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THE
BESSEMER PROCESS
AND WORKS
IN
THE UNITED STATES.

From the "Troy Daily Times," July 27, 1868.

NEW YORK:
D. VAN NOSTRAND, No. 192 BROADWAY.
1868.

A TREATISE

ON THE

METALLURGY OF IRON

CONTAINING OUTLINES OF

THE HISTORY OF IRON MANUFACTURE
METHODS OF ASSAY, AND ANALYSES OF IRON ORES
PROCESSES OF MANUFACTURE OF IRON AND STEEL
ETC., ETC.

BY H. BAUERMAN, F.G.S.
Associate of the Royal School of Mines.

FIRST AMERICAN EDITION, REVISED AND ENLARGED.

With an Appendix
ON THE MARTIN PROCESS FOR MAKING STEEL
FROM THE REPORT OF
ABRAM S. HEWITT
United States Commissioner to the Universal Exposition at Paris, 1867.

Illustrated with numerous Wood Engravings.

NEW YORK
VIRTUE & YORSTON, 12 DEY STREET
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THE BESSEMER PROCESS.

THE PRODUCTION OF CHEAP STEEL IN AMERICA.—THE COMPLETION OF THE PARENT WORKS AT TROY.—DESCRIPTION OF THE VARIOUS BESSEMER WORKS IN THIS COUNTRY.—THE NATURE AND VALUE OF THE IMPROVEMENT.

THE changes beheld by Rip Van Winkle when he last descended the Kattskills, are hardly remarkable when compared with the chemical and engineering wonders to which we have awakened after twenty years of comparative lethargy. All on a sudden fresh fountains of force and new veins of precious material seem to have burst out of the earth; already they have possessed every artificial motion and structure, and are embodied in the organization of every-day life. Among the more remarkable of these changes—ocean telegraphy, steam transportation, and engineering construction—the most wonderful and far reaching—the realization of the alchemists' dreams, is Chemical Transformation. All the world is the stage upon which its wonders are the glittering spectacle, and we turn rather to the Arabian Nights than to sober history for an index to the coming acts. Yet the powers behind the scenes are neither furies nor fairies, but brains and brawn. It is neither magic nor alchemy, but straightforward, inductive reasoning and downright, patient, organized, costly work that lays open the great unknown and utilizes its treasures.

The modern revolution in metallurgy is, perhaps, less striking, but more wonderful than all the others. The wonder of ocean telegraphy is new every morning, while the furnace smokes silently and unobserved. But the smoke of the furnace will tell you tales of nature's secrets unlocked, of startling transformation, of fathomless search, of baffling experiment, of patient endeavor, of endlesss obstacles, of intellects gone mad, of money burned up, of a forlorn hope fighting against the Powers of the Air, but fighting to win.

Of all the agencies in the material progress of the times, iron, in its various forms and combinations, holds the first place. Its loss would be a calamity only surpassed by the loss of bread; while its cheaper, wider, and better production would electrify every human enterprise. But cheap iron is not to be had for the asking. Nature has surrounded it with every poison and subjected it to every malady. Sulphur, phosphorus, silicium, and endless impurities hang about it from the ore-mine to the market, and its medicines—Manganese, Chromium, Aluminium, and its various healthful alloys, are subtle and intractable. Too little carbon is as injurious as too much; combinations helpful for one use are hurtful for another.

And the production of cheap iron draws not only upon chemistry but on engineering for constant and vital aid. The production and maintenance of uniform and excessive heat, the quality and structure of vessels to resist it; the multiform and powerful enginery to handle and fashion the incandescent masses, the strength and quality of materials and proportions to resist the strain and wear; the toilsome and hazardous searches for knowledge, the education of labor; the liberal risks of money, the conservation of capital—these are some of the clashing and difficult problems that beset the production of iron in the form of cheap and useful alloys.

We have thus briefly referred to the grandeur and the difficulty of the great material problem of the age, not to account for failure, but to celebrate success. Among the many workers who have steadily advanced the art, a few strong men have revolutionized it; and the names of Cort, Neilson, Siemens, and foremost of all BESSEMER, will be landmarks in its history wherever and as long as iron is used.

We purpose to allude briefly to the composition and production of iron and steel, and to the nature, conduct, value, and history of the **Bessemer Process**, and to describe in some detail the Bessemer works and manufacture in this country, and more especially as established in this place by our distinguished citizen, the Hon. John A. Griswold, upon the occasion of the first production of steel rails at his works.

THE OLD PROCESSES.

The ore of the mines is iron combined with an excess of oxygen and mixed with numerous impurities. The great body of white hot coal in the blast furnace not only melts the ore, but sublimates its volatile parts, liquefies others, and gives to others still the power to combine with the fluxes put in with the ore and to run away in slag. But in clearing one obstacle the iron thus set afloat grounds on another. The carbon of the coal only turns out the oxygen from the ore to sit down in its place; so that the crude or pig iron of commerce is a compound of iron with say five per centum of carbon and two or three of silicium and other metals and minerals, helpful or hurtful as the case may be, which the blast furnace process either put in or failed to remove. Cast-iron is comparatively weak, fatally brittle, and utterly incapable of being wrought. To render it strong, ductile, and malleable, the carbon, silicium, and other impurities must be removed; but the poison of yesterday is the medicine of to-day, and we now put it into the bed of a reverberatory furnace and doctor it with oxygen, externally applied in draughts of air, and taken internally in powders of ore and forge scale. The patient is meanwhile kept very warm, about 3,000° Fahrenheit, which so relaxes the hold of the disease that the oxygen easily spirits it away in the form of gases, and the squeezers and rolls bleed it off in the form of slag. This is puddling, and the rejuvenated product is wrought-iron, which is the nearest approach to pure iron that we have in the engineering arts.

Wrought-iron, however, is not cast into solid homogeneous masses of any dimensions like steel, it is only produced in small masses which must be welded together; but the high plastic heat necessary to squeeze the particles into contact, is also the temperature of spontaneous chemical change; so that the ever-lurking oxygen of the air again seizes the iron and reconverts its surface into a kind of ore, and therefore welds are uncertain. Wrought-iron is soft, it is not sound and homogeneous, and compared with steel, it is weak. To produce steel, then, we again retrace our steps and put in carbon, of which we just now had too much. The wrought-iron is broken up, mixed with carbon and manganese in a crucible, melted, and cast into ingots of steel—the highest refinement?—no, pure iron would be utterly unfit for the engineering arts; but the highest combination of natural substances known in the arts—steel, an alloy of iron, and from a quarter to a whole per centum of carbon, according to the hardness required, and traces of other metals.

You will thus observe that to make steel, you take a little iron and a little carbon and a few condiments, apply a hot fire, and there you have it—steel—as simple as the cookery book. But oh! the years of conflict with elements all too subtle and poisons all too willing, before the little niceties that make the difference between success and dead failure were found out at all—and the labor, the care, the skill, the fuel, the machinery, the power—not in a little laboratory upon which you can turn the key, but throughout acres of bricks and mortar, boilers and engines, rolls and hammers, furnaces and crucibles, all surging with pent-up energy and fervent heat, day and night, year after year. So that the receipt for making steel would rather be, take great perseverance and equal portions of the knowledge of books and the knowledge of practice—mix them well with no end of money, and then if you know how and have good luck, you can make a grand success of it.

THE BESSEMER PROCESS.

In the year 1855, Mr. Henry Bessemer of London, aware, indeed, of certain attempts at a cross-cut from pig iron to steel, but rather discouraged than stimulated by previous failure, determined to avoid the roundabout and costly processes heretofore pursued. He said crude pig iron is iron and much carbon—steel is iron and little carbon. I will burn out the excess of carbon, and with it the other impurities; and the carbon itself shall be the fuel to burn them out. I will blow air into the liquid iron; the oxygen of the air at that temperature has greater affinity for the silicium and the carbon than it has for the iron, and so will take them away, and leave either pure iron, or iron carburized to any degree required, in proportion to the extent of the blowing, which is steel—steel of every quality, from hard and white for tools, to soft and gray for the ten thousand purposes of machinery.

To the hearing of practical iron workers, a man never told a more splendid nor a wilder dream than this. But he fought it out on that line. He spent a large fortune of his own, and the fortunes of his sanguine friends. He struggled with every variety of failure and embarrassment. He smarted under jeers and opposition. He saw rivals toiling on every hand to mend the weak places in his system, and call it their own. He has not, indeed, realized quite all he set out for, in its perfection, nor has he avoided nor ignored the help of other men. But although the Bessemer process to-day cannot turn every variety of pig iron into steel, it is applicable to three-quarters of the good irons of commerce; it is, with fair materials, less liable to uncertainty, and less dependent upon skill than the processes it avoids; it produces, at a slightly increased cost, a material twice as strong as wrought-iron, and what is of vastly greater importance, perfectly solid and homogeneous—a material singularly well adapted to rails, axles, shafting, boiler and ship plates, and heavy machinery. Already the product in various countries is some two hundred and fifty thousand tons per year.

EARLY DIFFICULTIES OVERCOME.

Before considering the conduct of the Bessemer process, it is necessary to bear in mind, 1st, that the grand value of Bessemer metal over puddled metal, is due to its being produced in a *fluid state;* 2d, that while cast-iron is easily liquefied, at a temperature of 3,000°, wrought-iron or soft steel can only be kept liquid at a temperature of at least 5,000°, which is quite beyond the convenient and practicable capacities of fuel and furnace material as ordinarily employed.

For nearly a century, the partial decarburization of pig iron has been accomplished by blowing air upon (and in some cases into) a melted mass of it. But the liquidity of the mass was only maintained by contact with an intense coal fire. The combustion of the carbon by the air was so slow and so limited in extent, that the iron was rather chilled than heated by it. This was the "finery" process, and was merely preparatory to puddling; the product was still cast-iron.

Some years before Bessemer began his experiments, Mr. William Kelly, of Kentucky, advanced the finery process by a great stride, but left it still far short of practical steel making. He blew air into the iron just smelted from the ore, and lying in the hearth of a blast furnace, and partially decarburized it, but not without the liquefying agency of the mass of fuel above. He afterwards blew streams of air into melted iron contained in a covered brick vessel or chamber, without fuel. The almost invariable chilling of the iron, after repeated experiments with various forms of apparatus, and extending over several years, led to the suspension of further trial in this direction. The subsequent success of the Bessemer process, however, revived the claims of Mr. Kelly. The precise legal status of the two inventors has not, fortunately for the public as well as for the parties immediately interested, been brought to test, the various interests having been combined.

At this point we are prepared for the inquiry—What *is* the Bessemer process? If the old finery did not fulfil the theoretical specification, Kelly's certainly did. Here were carbon and silicium in the iron, but all ready to leave it upon the heated appeal of oxygen; here was plentiful oxygen spread over and bubbling through it, and here was the ample heat of 3,000°. Still the reactions were irregular, and impracticable.

Just here Mr. Bessemer introduced a radically new element, that made all the difference between failure and success. To describe his process as the introduction of oxygen into melted iron, is to play Hamlet without the prince. Bessemer's is not strictly a chemical process. The chemical reactions will look out for themselves, but they must have an adequate chance, and this is what Bessemer for the first time gave them, by mechanical means, viz.: *the mechanical force of numerous blasts* —not sluggish drafts, but roaring *blasts* of air, blowing the melted iron all into spray, so as to give the oxygen and the carbon hundreds of square feet of surface contact, so that every drop of iron should be enveloped with air. Thus, and thus only, the combustion is so perfect and rapid, and so diffused throughout the whole mass, that the two grand desiderata are attained—1st, the decarburization is effected without the use of other fuel; and 2d, the product is liquid and can be cast into homogeneous masses.

To accomplish these results, Mr. Bessemer developed the radically new machinery and apparatus which, with various extensions and modifications, is everywhere used. It consists, principally, of the converting vessel mounted on trunnions, and so shaped that the liquid metal can lie quietly in it while the tuyeres (air admission) and the entrance or mouth of the vessel lie above the metal line, and so that the mouth becomes a chimney and the tuyeres are brought beneath the metal, when the converter is turned upright. He also, after great trouble, developed a refractory material (chiefly silicious stone), and a mode of lining the converter adequate to the great heat and wear. The general arrangement of casting pit, ladle, ladle and ingot cranes, regulator, and other plant to be hereinafter described, were rapidly developed by Mr. Bessemer. During ten years of his first practice, he advanced the machinery of the new art to a much higher degree of perfection than has yet been attained to in the old processes.

But Mr. Bessemer had no sooner conquered this difficulty than he encountered another and equally serious one. Except when a few of the choicer irons were employed, entire decarburization left the product "red-short," or incapable of malleability at a red heat, and therefore utterly useless. To stop the blowing at such a point as should leave in sufficient carbon to cure the red-shortedness and constitute a mild steel, was on the whole impracticable, because there is no adequate indication of *degrees* in decarburization, and the accuracy of blowing through a fixed time, would be impaired by varying heat and other circumstances. Here, then, were the impossibility of definite degrees of decarburization on the one hand, and the spoiling of the product by complete decarburization on the other hand.

In studying Mr. Bessemer's numerous patents and writings, we observe that he clearly understood this difficulty, and approached very near to its solution. Indeed, he rather vaguely described, in several patents, perhaps without seeing the end from the beginning, substantially the remedy afterwards patented by Mr. Robert Mushet.

The indications of complete decarburization by blowing air into melted iron, are as distinct as the time of day on a clock. The flame at the converter mouth suddenly decreases in volume, and loses—not its own brightness, but its power of illuminating other things. But the product is valueless. Mr. Bessemer vaguely conceived, and Mr. Mushet definitely specified the finishing touch in the great art—*recarburization.* A definite weight (three to seven per centum) of a pig iron, containing not only carbon but manganese (either Franklinite or Spiegeleisen), is melted and run into the decarburized iron. At this excessive temperature—not less than five thousand degrees—the oxygen and other impurities that make the iron red-short, come out of it with great commotion, and enter into the carbon and manganese thus added, forming an intense flame and copious slag. A part of the carbon combines with the iron, thus producing steel. All this is the work of a moment, and the thorough reaction is due to the excessive temperature. The oxygen which is removed by the carbon (or chiefly by the manganese), was produced by the oxydation of some of the iron, by the blast of air. This, and the sulphur, and some other impurities, now removed by the manganese, were what made the product red-short before recarburization. The steel is now cast into ingots, which are malleable at a high heat.

But Mr. Bessemer's troubles did not end here. The product was still uncertain, though often uniform and excellent. Some subtle impurity was still lurking in some obscure corner—now appearing and now retiring. To find it, Mr. Bessemer put every iron and material employed, through a costly and thorough course of chemical analysis, and so discovered phosphorus to be the arch-enemy. And to this day, irons containing above two hundredths of one percentum of phosphorus cannot be employed to advantage. Experiments to remove or neutralize it are in progress, and greater obstacles than this have been overcome. Mr. Bessemer also determined the amounts of other materials—silicium, sulphur, etc. —that affected his process, and with Mr. Mushet's assistance (satisfactorily acknowledged) has presented to the world, not merely a theory, but a perfected process and adequate machinery for carrying it out. It will thus be observed, that however greatly the public is indebted to Mr. Bessemer's inventive powers, it owes still more to his indomitable *pluck*.

PATENTS AND WORKS.

The Bessemer patents in England are some twenty in number, and embrace not only the process, but the essential machinery, and many collateral subjects and defensive claims. In European countries the more important features have been secured by letters patent. Complete protection has been obtained in the United States, not only for all the essential parts of the Bessemer plant and process, in ten separate patents, but of the Kelly and Mushet inventions, and of various improvements by Holley and others. All these patents have been combined by purchase and compromise, and are held by Messrs. Winslow, Griswold, and Morrell, trustees for the parties interested. Under them, licenses have been granted to the various establishments to be hereinafter described, viz.:

The Bessemer Steel Works, Troy, New York; Messrs. John A. Griswold & Co. Z. S. Durfee, Manager.

The Pennsylvania Steel Works, Harrisburg, Penn.; S. M. Felton, Prest. A. L. Holley, Chief Engineer.

The Freedom Iron and Steel Works, Lewistown, Penn.; John A. Wright, Prest. R. H. Lee, Superintendent.

The Cleveland Rolling Mill Co., Cleveland, Ohio; A. B. Stone, Prest. John C. Thompson, Superintendent.

The Wyandotte Steel Works, Wyandotte, Michigan; E. B. Ward, President.

The National Iron Armor Co., Chester, Penn.; William B. Reaney, President.

The Cambria Iron Works, Johnstown, Pa.; Chas. S. Wood, President. Geo. Fritz, Chief Engineer.

The foreign Bessemer works are as follows: In Great Britain, Henry Bessemer & Co., Sheffield; John Brown & Co., Sheffield; Charles Cammell & Co., Sheffield and Penistone; Weardale Iron Co., Tow Law, Durham; Thomson & Armstrong, Normanton; J. M. Rowan, Glasgow; Samuel Fox & Co., Deepcar; Lloyds Forster & Co., Wednesbury; Bolton Steel Works, Bolton le Moors; London and North Western Railway Works, Crewe; Lancashire Steel Co., Gorton; Mersey Steel and Iron Works, Liverpool; Manchester Steel and Railway Plant Co., Ashbury; Barrow Hæmatite Steel Co., Barrow; Guest & Co., Dowlais; Ebbw Vale Co., Ebbw Vale; Bessemer & Sons, Greenwich. In France there are 5 works; in Belgium 1; in Prussia 7, including the celebrated establishments of Krupp and of the Bochum Co.; in Austria 10; in Sweden 12; in Russia 1; in India 1. The whole number of converters in use is from one hundred and thirty to one hundred and fifty, of various sizes, from one ton to ten tons, and the total annual capacity of them all is not less than half a million of tons.

THE TROY WORKS.

History and Organization.—The Bessemer patents were purchased in England for Messrs. Winslow & Griswold, by Mr. A. L. Holley, and the Mushet patents for other parties (now represented by the Trustees), by Mr. Z. S. Durfee, at about the same time. Mr. Holley built the experimental works at Troy, started them in February, 1865, and completed the new works, or "five-ton plant," early in 1867, Mr. John C. Thompson then being superintendent of manufacture. Mr. Holley then took charge of the Pennsylvania Steel Works, and Mr. Thompson soon after, of the Cleveland works. Mr. Durfee having previously built an experimental works at Wyandotte (afterward run with success by Mr. R. W. Hunt, now of the Cambria works), then took the management of the Troy works, built the forge and introduced various improvements to be farther referred to.

Situation.—The location of the Troy works upon tide-water and the Erie and Champlain canals, and, therefore, accessible to coal and the general market by means of the cheapest transportation; in the centre of a remarkable and varied iron supply, from the Hudson and Housatonic valleys, from Vermont and Lake Champlain, from the promising Adirondack region, and from the markets of the South and West; this general location is not more eligible than the immediate sites of the works controlled by Mr. Griswold. The Bessemer Works are situated on a level plot, some fifteen acres in extent, with a rock bottom for foundations, well above high water, and bounded on one side by one thousand feet of tide-water, and on the other by the same length of Hudson River Railway. The more remarkable feature of such a site, is a constant water-power of one hundred horse, with thirty-four feet fall, supplied by an underground, four and a half feet trunk, from a line of ponds and reservoirs extending for miles above, and conducted from the wheel-pit to the river by a covered brick race-way.

Buildings.—The Bessemer building is of brick, one hundred and seventy-eight feet long by sixty-five feet wide, and twenty-two and a half feet high in the clear. A pair of five-ton converters and their appurtenances occupy one hundred and ten feet of its length. The remainder contains the experimental two-ton converter and its apparatus, and is of sufficient size for a pair of two and a half or three-ton converters, soon to be erected. The cupola building, joined to the east or railroad side of the Bessemer building, is a brick structure forty-four by twenty-four feet, and thirty-feet high in the clear. At one end of the Bessemer building, and forming a continuation of it, is a wooden building one hundred and sixty feet long by seventy-five feet wide, and twenty-two and a half feet high, designed for hammers and other machinery for working up ingots. The converting building and forge are roofed with slate, and mounted by a continuous lantern three hundred and thirty-eight feet long and twenty-one feet wide. At the other end of the converting building is a four-story brick structure sixty-five by thirty-six feet, and thirty-nine feet high from the ground in the clear, covered with a hipped slate roof and a lantern twelve and a half by forty-one feet. The basement contains a fifty-horse Collins turbine, employed to drive the machinery and blowers above; also, a machine for grinding stone for converter linings (a nine foot pan and two six-feet rolls), and a seventy-pound tilt hammer for testing ingots. The second or ground floor is a machine shop fitted with the necessary lathes, planers, and tools for the maintenance of the works. The third and fourth floors are for the storage of tuyeres and the miscellaneous materials employed in the manufacture. A power lift operates from cellar to attic. A No. 6 Root pressure blower and a five-foot Dimpfel fan and their driving machinery for supplying blast to the cupolas and furnaces, and a No. 2 Bogardus mill for grinding the finer fire materials, are placed upon the third floor.

The above-described buildings form a continuous structure of eighty-nine feet maximum width, and four hundred and seventy-four feet length. Upon the west, or river-side of these buildings (a sixty feet street lying between), stands a wooden building sixty by sixty-five feet, and sixteen feet high in the clear, with a high attic for storage, and a continuous lantern above. Here are the boilers and the blowing and hydraulic engines. These buildings, with the offices, store-bins, and railways, form a complete establishment, capable at present of producing forty tons of ingots per day, or sixty to seventy tons per day of ingots, and a considerable amount of forgings and finished work, when the two-ton experimental converter is replaced by a larger plant and the forge is fully occupied.

MACHINERY.—The blowing engine consists of two forty-eight inch air cylinders, four-feet stroke, lying at the two ends of a heavy bed-plate, forty-three feet long, five and three-quarter feet wide, and one and three-quarter feet high, and connected to a common crank upon one end of the steam-engine shaft. The steam cylinder lies by the side of one of the air cylinders, upon a framing of its own, and is thirty inches in diameter. Its piston, of four-feet stroke, is connected to a crank on the other end of the main shaft. The air cylinders, being connected to one crank, operate like a single cylinder, and cause a pulsation in the blast, which is in other engines avoided by cranks at right angles. But the large air receiver, eight feet in diameter, by eighteen feet high, so equalizes these pulsations that the pressure gauge shows less than a pound variation, and does not at all embarrass the indications at the converter mouth by which the decarburization is determined. The tendency to irregular motion, due to a single steam cylinder, is also corrected by a fly-wheel of twenty-one feet diameter and twenty and a half tons weight. These are valuable results, as they will lead to economy in construction. The steam engine was constructed upon the plans of Mr. Geo. H. Reynolds, and embraces some novel features, among others, a framing peculiarly strong in the line of strain, and a condenser and air-pump below the cylinder, formed between the frames; the air-pump is double-acting, and is driven by an arm from the cross-head. The injection water comes from the reservoirs before referred to. The valve motion is the long slide, with fixed independent slide cut-off. The boilers, four in number, are fifteen feet long by five feet in diameter, having forty-two four and a half inch return flues, five by five and a half feet grate, and three by four feet domes, and form a battery, inclosed in brick, with cast-iron fire-fronts of novel and good construction. The smoke stack is of sheet iron. The blowing machinery was constructed at the Delamater Iron Works in New York.

The pumping engine for working the cranes and hydraulic machinery in the Bessemer Building is a Worthington "Duplex," with fifteen-inch stroke, two twenty-inch steam cylinders, and two seven and a quarter inch water cylinders, working at three hundred and fifty pounds pressure per square inch. The feed pump for the boilers is also a Duplex. This is probably the most trustworthy and economical class of hydraulic machinery known.

THE EXPERIMENTAL BESSEMER PLANT has been variously changed, and has developed a vast amount of useful knowledge concerning irons, materials, and processes, besides producing some thousands of tons of marketable steel. It consists of a two-ton vessel, or converter, five feet in diameter, rotated by hand-gearing, and supplied with melted iron by a No. 2 Mackenzie cupola, having a movable bottom, and thus being the equivalent of two cupolas. The main crane is worked either by hand or by a hydraulic cylinder attached to the crane chain, and lifts the ladle crane as well as the ingots and moulds. The recarburizing material is melted in crucibles instead of air furnaces. This change, developed by Mr. Durfee, promotes the uniformity of the product, and does not greatly, if at all, increase its cost.

THE "FIVE-TON PLANT" consists, firstly, of two cast-iron converters, fourteen and a half feet high by eight feet ten inches diameter, standing side by side. In their rear is the wall of the converting house, pierced with arches leading to the melting house, and supported by heavy buttresses, upon which stand the hoods and chimneys to conduct the flame from the converters. In their front is a circular casting pit, thirty-four feet in diameter and thirty inches deep (having deeper covered pits for large ingots), with a ladle crane in the centre and three ingot cranes at its sides, upon the general level. The ladle crane, of fifteen tons capacity, is a hollow cast-iron post or ram, standing in a fifteen-inch cylinder (six-feet stroke), and reaching to a support in the roof. It carries a fifteen and a half feet jib, consisting of two wrought-iron arms held up by diagonal tie rods, and forming a railway upon which the carriages supporting the ladle are moved, radially, by a rack and pinion. The ladle is removable by one of the ingot cranes (for repairs of lining after each heat), and is about four feet high and of the same diameter for a five-ton charge, or double this size when it is to receive the product of both converters. It is mounted on trunnions, and rotated by a worm attached to the carriage. It is lined with loam, dried in an oven standing in one corner of the building, and heated by being turned over a small furnace in the pit. The steel is let out of a hole in the bottom of the ladle, into the ingot moulds, by means of a fire-clay nozzle, two inches in diameter, and a fire-clay stopper, operated by a slide and lever fastened to the outside of the ladle. The ladle crane is rotated by hand gearing, and is moved very easily, as it rests upon frictionless water.

The two side ingot cranes are constructed like the ladle crane, except that they have a single carriage on the horizontal jib, with a chain depending. The ram is of twelve inches diameter, the stroke nine feet, the length of jib twenty-two feet, and the capacity eight tons. These cranes swing over the respective converters and over one-third of the pit each, and over a considerable floor space, and are chiefly used for lifting ingots and moulds. The central ingot crane has an eighteen feet jib, a nine-inch ram, and lifts three tons.

All the cranes are operated from a raised platform or "pulpit," by means of geared hand-wheels, opening brass three-way and four-way cocks, like gas cocks, only seven inches in diameter, and thus admitting or exhausting water at the 350 lbs. pressure of the pumping engine before mentioned. From the same "pulpit" are operated the valves of two hydraulic lifts of twelve inches diameter, fifteen inches stroke, and eight tons capacity, standing under the converters for taking them apart, and also the two eight-inch screw valves for admitting air to the converters, and also the valves of the seventeen-inch (six-feet stroke) hydraulic cylinders for revolving the converters on their trunnions by means of racks, and pinions of three feet diameter, twelve-inch face, and five and one-eighth inches pitch. The air and water are conveyed from their respective engines to the regulator under the "pulpit," and from the regulator to the cranes, etc., by underground pipes. A boy working the regulator handles can thus not only perform the work of some fifty men, but he can do it with perfect precision and promptness. In fact, men enough could not be got into position to do the work, or stand the heat. The hydraulic cylinders are arranged to be "blown out" in freezing weather, by admitting air instead of water.

A railway with sidings, in the building and yard, joins the Hudson River Railway track.

The melting-house contains a No. 6 Mackenzie cupola with three revolving bottoms, and is the equivalent of three cupolas. An eight-ton crane built like the ingot cranes, but having eleven and a half feet lift, raises a platform with barrows of iron and coal from the ground level (which on this side of the works is four and a half feet higher than the converting floor) to the level of the cupola and air-furnace charging floor. The melted iron is tapped out into one of two ladles standing on eight-ton scales. When a ladle is filled, it is weighed, so that the exact percentage of the recarburizer may be ascertained, and then raised by the same crane that lifts the materials to the cupola. The ladle hanging by its trunnions in a frame is then turned over by a worm attached to the frame and emptied into a spout that conducts the melted iron to the mouth of the converter. The air furnaces for melting the recarburizer are placed over the oven, at one end of the converting building, in a line with the converters, and at the level of the cupola charging floor. The recariburizer (melted manganesian pig iron) is tapped into a ladle which runs upon an overhead railway from the furnace to the converters.

"A Blow."—However interesting the foregoing facts may be to steel makers, or however dull to general readers, a " blow "—the thing itself—is remarkable alike to the scientific and the unprofessional observer, especially at night when the splendor of this intense and concentrated combustion is not rivalled by sunshine, and when the imagination invests each ponderous machine with mysterious life and awful energy. The cavernous room is dark, the air sulphurous, the sounds of suppressed power melancholy and deep ; half-revealed monsters with piercing eyes crouch in the corners, spectral shapes ever flit about the walls, and lurid beams of light anon flash in your face as some remorseless beast opens its red-hot jaws for its iron ration. Then the melter thrusts a spear between the joints of its armor, and a glistening yellow stream spirts out for a moment, and then all is dark once more. Again and again he stabs it till six tons of its hot and smoking blood fill a great cauldron to the brim. Then the foreman shouts to a thirty-foot giant in the corner who straightway stretches out his iron arm and gently lifts the cauldron away up into the air and turns out the yellow blood in a hissing, sparkling stream which dives into the white-hot jaws of another monster—a monster as big as an elephant with a head like a frog and scaly hide. The foreman shouts again, at which up rises the monster on its haunches, growling and snorting sparks and flame.

What a conflict of the elements is going on in that vast laboratory ! A million balls of melted iron, tearing away from the liquid mass, surging from side to side, and plunging down again only to be blown out more hot and angry than before—column upon column of air, squeezed solid like rods of glass by the power of five hundred horses, piercing and shattering the iron at every point, chasing it up and down, robbing it of its treasures only to be itself decomposed and hurled out into the night in roaring blaze.

As the combustion progresses, the surging mass within the converter grows hotter, throwing out splashes of liquid slag —and the discharge from its mouth changes from sparks and streaks of red and yellow gas, to thick, full, white, howling, dazzling flame. But such battles cannot last long. In a quarter of an hour the iron is stripped of every combustible alloy, and hangs out the white flag. The converter is then turned upon its side, the blast shut off, and the recarburizer run in. Then for a moment the war of the elements rages again ; the mass boils and flames with higher intensity, and with a rapidity of chemical reaction sometimes throwing it violently out of the converter mouth ; then all is quiet, and the product is steel—liquid, milky steel, that pours out into the ladle from under its roof of slag, smooth, shining, and almost transparent.

THE ARRANGEMENT of all the Bessemer works in this country, excepting the works at Lewistown, and the experimental works at Wyandotte, is substantially in accordance with the plans of Mr. Holley. These plans preserve all the old features and proportions affecting the process, but especially as carried out in the second works built by him at Harrisburg, they considerably increase the convenience of manufacture and repairs, and the capacity for product. In the English works, as designed by Bessemer, and blindly followed there, the converters stand at opposite sides of the casting-pit, thus narrowing by half the casting-room as compared with the Troy works, where the available space for moulds is over seventy feet in length. In England, the working space around the pit and under the converters is sunk below the general level, which is inconvenient and wasteful of room. At Troy the converters are set at a height which not only provides a continous working space upon the general level, but allows another new feature—a second floor extending around the converters, standing upon which, workmen get at all parts of the converter, put materials into it, dress the spouts for conveying melted iron, and work upon the converter-bottoms when they are run out for repairs.

The tuyeres, or blocks of fire-brick pierced with holes, through which the air is blown up into the iron, last but six to eight heats, and their renewal has hitherto caused much delay. In these works the converter-bottom is removed by means of a hydraulic lift and a carriage running out at the side of the converter, where it can be conveniently got at. The bottom may be replaced when required, by a duplicate bottom, previously furnished with new tuyeres, dried and heated. In the English works the crane capacity is inadequate to rapid working. In the Troy works, the ingot cranes are three instead of two in number, the ladle-crane is arranged for more motions of the ladle, and all the cranes are lightened and cheapened by means of top supports. Various novelties and conveniences have been added to the regulating apparatus, ladle-stopper, and other parts. The cupola furnace has been adapted to melting iron for conversion, by employing a ladle on a scale to weigh the metal, and has thus superseded the air furnace, saving cost and facilitating manufacture.

Mr. Holley introduced at Troy, and perfected at Harrisburg, a method of casting a number of ingots at one pouring, thus saving scrap and wear of moulds, and producing better ingots of more definite weight. The moulds are set upon an iron bottom or flask lined with loam. The steel, let into the central mould, passes through runners in the flask into the bottoms of the surrounding moulds, and all the moulds are filled together. Mr. Durfee has since perfected another apparatus for bottom casting—a substitution of removable runners of cast-iron instead of loam, between the bottoms of the moulds—and is obtaining excellent results.

The perfection of the Bessemer process in England, left much to be learned in America. New irons, new refractory materials, different coals, and unaccustomed labor, had to be tested and adapted, and various different conditions and requirements of manufacture had to be considered. When the ingots were produced, there was little suitable skill and machinery in this country to work them properly; and so, although an excellent quality of steel was produced at Troy, at the first blow in 1855, all these new labors were vigorously undertaken, at great expense. As a result, the quality of American materials is now well understood, the various requirements of machinery and treatment are well developed, and various improvements and economies in construction and manufacture are fully established.

If we except a few of the works on the Continent, where irons are peculiarly adapted to Bessemerizing, it is probable that no better or more uniform steel is produced anywhere in the world, than at Troy.

THE RAIL MILL.

The new rail mill of Messrs. John A. Griswold & Co. has been completed and started upon a large order for steel rails, during the present week.

This establishment (the Rensselaer Iron Works) is situated between the Hudson river and the Hudson River Railway, within the city of Troy, and a mile above the steel works. The yard, next the river, is two hundred and fifty feet wide, with a wharf one thousand feet long. The railway yard is sixty feet wide, and of the same length.

The new mill built by Colonel George Babcock, superintendent—Robert P. Banfield, master mechanic—is a rectangular brick structure, four hundred by one hundred feet in plan, and twenty-five feet high, with a continuous lantern eighteen feet wide by six feet high. The walls are sixteen inches thick, with pilasters thirteen feet apart, upon which the roof trusses rest. The trusses are of wood; the covering of slate. The doors slide vertically in heavy iron frames built into the walls. Gothic windows alternate with the doors, and above these the walls are pierced with round windows.

The end of the mill next the old rail mill, contains eight heating furnaces—two pairs at the end, and a pair at each side. The engine stands at one end of the train, and the saws and hot bed are near the centre of the building. The northern portion of the mill is devoted to a steel bar train and an iron merchant train.

The rail train engine, by Starbuck Brothers, Troy, is a particularly well built and smoothly working machine. It stands on ten feet depth of brick masonry, resting on six feet of stone and concrete, which is supported by twenty feet of solid piling. The engine is of the "steam-hammer" pattern, vertical, condensing, and directly connected to the train. A solid bed plate supports two side frames, upon which there stands a fifty-four inch cylinder, and between which work the cross-head (thirty-six inch stroke) and the beam for driving a thirty-inch air pump (eighteen-inch stroke) situated at the end of the bed plate. The connecting rod (seven and a half long) and the piston rod, and other parts are of Bessemer steel. The fourteen-inch shaft (twenty-four inch length of journals) is cranked, so as to be connected to trains at either end. The fly-wheel is of twenty-five feet diameter, with a seventeen by twenty-inch rim, and weighs sixty tons. The valve is Davis' piston, made double, or, in fact, two eight-inch valves side by side, to get ample port area. The packing of these valves is solid, but may be set out at will; the valve is the equivalent of a slide, and perfectly simple. The steam pressure comes only on the ends of the two pistons forming the valve, and the exhaust pressure between them, so that there is constant equilibrium, and the valve is easily worked under steam by the starting bar. Snow's governor is attached to the cut-off. The engine may be changed to non-condensing, by opening a valve in the exhaust-pipe. The engine runs at seventy revolutions, for a twenty-one-inch train.

The fan engine, standing near the other, and of similar pattern, has a fifteen by twenty-two inch cylinder, and is belted to a line of shafting above, which drives two overhead six-feet Sturtevant blowers on either side of the mill, at eight hundred revolutions. An air pipe runs around over the furnaces, from blower to blower, with branches down to the ash pits.

The rail train is a twenty-one inch three-high train of the Fritz pattern, standing on a brick foundation, with a heavy oak cushion between. Steel rails are bloomed from nine-inch ingots, and then roughed down and finished at a reheat. This is done in three sets of rolls, with twenty-one to twenty-five passes, according to the pattern. At present, a top and bottom train is attached to the end of the steel rail train, but it will ultimately be replaced by the ordinary roughing and finishing rolls for iron rails; and the old rail mill will then be devoted to all top and bottom, puddle, breaking down, and preparatory rolling for iron rails.

Instead of the saw carriage running up to the saws, as usually practised, the saws are hung upon frames, which swing up to the rails as they lie on a fixed way, and are driven by belts from an overhead shaft that is supported by stands movable on a bed-plate. The engine is fixed to the same bed-plate.

The hot bed is seventy feet long, with a straightening plate in the middle, and a short raised table at either end. The rails forming the hot bed lie on rollers working in the tops of iron posts set upon masonry, and can thus expand without buckling.

At each end of the hot bed there is a straightening press, with a bell-crank straightening lever worked by means of an eccentric and a geared shaft, by a steam engine attached to the bed-plate. Behind the hot bed are two punching machines of similar construction, driven by separate engines, and each arranged to make the fish bolt holes and the spike slot, by means of a horizontal and a vertical punch. The rails are taken out of the mill to the wharf or to the railway, by means of cars running on tracks with suitable turn tables.

The waterworks consist of a fifty-thousand gallon iron tank, sixteen feet in diameter, forming the top of an octagonal brick building twenty-four feet high, in which there is a duplex Worthington pump, taking water from the river, and driven by a sixty-horse power tubular boiler in a wing of the building. The feed-pipes to the mill boilers are of wrought-iron, and may be warmed in freezing weather by steam. The boilers may be fed either by the Worthington pump, or by Giffard injectors, one of which is attached to each boiler, or by the main engine. The blow-off pipes from the boilers enter a large brick underground sewer, which also drains the boshes, the roll-pit, and the air-pump.

The heating furnaces and the boilers over them are well constructed, and are furnished with every appurtenance for convenience and safety. The flame from the furnace passes under and through the boiler to a chimney standing on iron columns outside the building. The ash pit, opening out of doors, under the chimney, is covered with a brick arch, shutting it off from the interior of the mill. There is an upper and a lower ash-pit door. The furnace plates are perforated, or rather they are heavy cast-iron spiders, securing the brick work, but leaving it well uncovered. A water door frame, got up at these works, is employed, and there are cast-iron boshes by each furnace. The boilers are thirty feet long by fifty-four inches diameter, with three thirteen-inch flues. The lower half of the end of the boiler, over the throat of the furnace, is recessed, so as to form a crown sheet for the flame to strike upon, and a chamber into which the flues open. A damper under the other end regulates the flow of flame under and through the boiler. Suitable air admission into the chamber under the boiler promotes combustion. The steam domes are three feet diameter by four feet high. A fourteen-inch wrought-iron steam pipe, with disc expansion joints, leads from the domes to the engine, and by a ten-inch branch to the merchant mill furnaces at the other end of the building. These pipes are thoroughly lagged. Besides the ordinary safety-valves, there are lock-up safety-valves provided by law; there are also float water-gauges and gauge-cocks. The boiler is inclosed in a chamber composed of cast-iron bottom plates and brick side walls, supported by trusses resting on columns. The floor of the mill is well covered with hexagonal plates. The maximum capacity is one hundred and twenty tons of rails per day.

The merchant end of the mill is furnished with a double billet shears and a merchant bar shears, each driven by separate engines. The condensing beam engine, forty-eight inches by seven feet, runs at twenty-five revolutions, and drives on either side a geared train, five rolls long, running two hundred and eighty revolutions, for small iron, and a sixteen-inch geared train, three rolls long, running fifty revolutions, for steel. Adjacent to the iron train are two heating furnaces with boilers, built upon the general plan above described. The steel is heated by a Siemens' furnace, supplied with gas by two producers. The capacity of these trains is six and one-half tons of small iron bars and rods, and fifteen tons of half-inch to five-inch steel bars and shapes per day.

The old rail mill is a brick structure, averaging three hundred and twenty by one hundred and twenty-five feet in plan. A condensing beam engine (the engine of the old steamboat "Swallow") with a sixty-inch by ten feet cylinder drives four two-high geared trains of eighteen-inch rolls, two for balls, one for breaking down, one top and bottom, and one (at present) for iron rails. The mill contains fourteen double puddling furnaces, four top and bottom furnaces, and the necessary heating furnaces and apparatus for one hundred and twenty tons per day of iron rails. The adjoining machine and smith shop is a brick building, thirty by one hundred and fifty feet, and a building thirty by one hundred feet is employed for storage and miscellaneous purposes.

THE PENNSYLVANIA STEEL WORKS.

These were the third Bessemer works started in the United States, and are in present extent of plant, as well as in proposed capacity, the largest in America. They were organized under the presidency of S. M. Felton, Esq., late President of the Philadelphia and Baltimore Railway, and under the direction and auspices of prominent railway men and engineers, such as Mr. Thompson, of the Pennsylvania Railway; Nathaniel Thayer, Esq., M. W. Baldwin & Co., Wm. Sellers & Co., Bement & Dougherty, R. P. Parrott, Esq., H. R. Worthington, Esq., Merrick & Sons, Morris, Tasker & Co., etc. They were built upon the plans, and started under the superintendence of Mr. A. L. Holley, now Chief Engineer. Mr. H. S. Nourse, late Assistant, is Superintendent, and Mr. John B. Pearse is Manager of the Bessemer Department and Chemist.

The Bessemer Department was started in June, 1867, and has been in constant operation. The ingots produced were mostly rolled into rails, at the Cambria Iron Works, Johnstown, Pa., until the starting of the Pennsylvania Steel Company's Rail Mill in May, 1868. The annual capacity of the present Bessemer Plant (two five-ton converters) is about ten thousand tons, and of the Rail Mill, thirty thousand tons. Additional converters will be erected from time to time.

The Pennsylvania Steel Works are situated in the heart of the iron and coal regions of the State, at Baldwin, a suburb of Harrisburg, which is a junction of canals and railways running in eight different directions. Upon a rectangular, high, level plat, one hundred acres in extent, lying upon the banks of the Susquehanna, between the Pennsylvania Railway and canal, the Company's buildings are arranged with reference to *systematic* growth. Room is left for the indefinite enlargement of each department with reference to ample yard-room and economical inter-communication by railway. These railways are of standard gauge, and of such curvature that cars from any of the lines radiating from Harrisburg can enter any building or yard. With such facilities for transportation, the present considerable distances between some of the buildings hardly amount to an inconvenience, and the great inconvenience so generally arising from huddling together the early buildings of growing works will be avoided.

The ground is a deep, solid gravel bank, well adapted to foundations, and its general level is twenty-five feet above low water, and three feet above the highest flood on record.

BUILDINGS.—The Bessemer building is probably the largest of the kind, being one hundred and fourteen feet long by one hundred feet wide, and twenty-five feet high in the clear, for one pair of five-ton converters. A lantern twenty-five feet wide and six feet high extends the entire length. The adjoining melting building is eighty-one by fifty-two and a half feet, and thirty-nine feet high, with a hipped roof, and a lantern eighteen by forty-four feet; and the attached engine and boiler building is one hundred and thirty-three by fifty-two feet, and fifteen feet high. They are solidly built of blue limestone from the adjacent quarries. The walls are eighteen inches thick, and twenty-four inches through the pilasters. The windows and doors are arched with brick. The roof trusses are of wood (for greater convenience of giving a top support to the cranes), and in the Bessemer building a sheet-iron sheathing or internal roof is suspended beneath them. The covering of all the roofs is slate.

The rail mill is two hundred and seventy-five feet by ninety-two and a half feet, with two wings, ninety-two and a half by forty-nine and a half feet each, and twenty-eight and a half feet high in the clear. It consists of a hipped wooden truss roof and a continuous lantern (twenty-six feet wide by four feet high), covered with slate and resting on wooden posts (ten by twelve inches, fourteen by fourteen inches, and four posts twenty-eight by twenty-eight inches), supported by stone piers. A permanent siding of wood, battened and having a continuous line of fourteen feet, semi-circular windows all around, extends from the eaves down to within nine and a half feet of the ground; but below this point the siding is formed of balanced doors opening upward, so that the building can be entirely closed in winter, while it may be turned into a mere shed in summer, and may be opened at any point for ventilation or for entrance and exit of vehicles.

The machine shop is of wood, battened, seventy-five by seventy-five feet, and twenty and a half feet high, with a lantern eighteen by seventy-two feet, and six feet high, and slate roof. One end is temporary, for enlargement. The line shafting is driven by a ten by eighteen-inch Hoadley portable engine, and the shop is completely furnished with roll and other lathes, planers, bolt-cutters, drill presses, a fifteen-ton Bement crane, a Bement end-lathe, etc.

The smith shop is fifty by fifty feet, and eighteen feet high, with a continuous lantern and slate roof; and is also arranged for enlargement. It has a central crane swinging over six double fires (without chimneys), and a Davy seven hundred weight steam hammer for forging test ingots and other work. Extensive store sheds for fire materials, etc., are erected at a convenient distance from the converting works. Water is carried to the machine and smith shops under the head of the rail mill tank. All the buildings are drained by a three-feet brick sewer running to the river.

The Company's boarding house is a brick building seventy by thirty-three feet, and three stories high, with twenty-six sleeping rooms. The workmen's houses are built of wood, on streets one hundred feet wide, with a thirty-foot alley between each pair. Each double tenement, or pair of houses, is twenty-eight by thirty feet, and two stories high, with two attached one-story kitchen buildings, and eight rooms with closet accommodation. The residence for the officers is a neat and commodious wooden villa, situated on an eminence overlooking the works and the river valley for many miles.

Plans are in hand, and proper places are left for the erection of extensive tyre, plate, and merchant mills.

THE BESSEMER PLANT is precisely like that at Troy, as to sizes and positions of converters and converter lifts, cars and platform, ingot pit and cranes, except that the central ingot crane is as large as the others, viz., twenty-two feet jib, nine feet lift. Two ovens with top entrances are sunk in the floor under the side ingot cranes. The flues of these ovens pass under brick bins for fire materials, to prevent their freezing in winter. The regulator, from which the hydraulic machinery and the cranes are worked, is the same as at Troy, although differently situated. The large converting house affords ample room for the storage of moulds, and the dressing of ladles and vessel bottoms, and for bins containing fire materials, charcoal, etc., and for a floor and a hand crane for moulding flasks, etc. Two ovens, eighteen feet long each, with end entrances and railways running out under the side ingot cranes, open into the converting room from the lower story of the cupola building. From a turntable under the central ingot crane, railways run in five directions out of the building, and under the other two ingot cranes. The railway to the rail mill passes over a ten-ton scale, and a two-ton platform scale is placed under one of the cranes, so that ingots can be weighed, assorted, and distributed with the greatest convenience and despatch. Upon the roof-trusses there is a hydraulic cylinder, operated from the regulator, which raises a one-ton drop (twenty-five feet fall) outside the building. The chain that raises the drop also unloads from cars the sculls, etc., to be broken up, and places them in position under the drop. The hydraulic machinery was built by H. R. Worthington, in New York.

At the front of the cupola building (opposite the converting building) there is a double two-ton vertical lift, operated by a line of shafting overhead, with openings to the stock-shed and yard. Coal wagons for a charge each, and iron wagons for a ton of pig each, are run upon the stock-house scale, loaded, run upon the lift, and hoisted to the ample cupola-charging floor, seventeen by twenty-five feet, and twenty-nine and a half feet high, or to the air-furnace floor, eleven and a half feet high. Two gangways, ten and a half feet wide, run through the cupola building from the front to the converting-room. Between these gangways are the lift, a mixing floor for vessel linings, the pit into which the cupolas are dumped, and an ample space behind the converters. At the sides of these gangways are racks for tuyeres, weighmaster's office, bins for fire materials (which are ground on the floor above), a cinder mill convenient to the cupola dumping pit, a fifty-horse oscillating engine to drive the line shafting in the top of the building, and the ovens opening to the converting-room. The next floor is eleven and a half feet high, formed of iron beams, arched between with brick and reached by the lifts and by two stairways. Centrally upon this floor stand three No. 6 Mackenzie cupolas in line (with space left for a fourth), and two twelve-ton ladles standing on platform scales, and arranged with worm-wheels to tip out the melted iron from the cupolas into spouts leading to the converters. This floor is connected with the converting-room by wide arches. An ample space is left upon it for getting at the converter bottoms. In one front corner of this floor is a building containing a five-feet Dimpfel fan for blowing the air and Spiegel furnaces, and a No. 6 Root pressure-blower for driving the cupolas. In the opposite front corner is a building containing a Blake crusher and a Bogardus mill for preparing fire materials. The two large spaces at the sides of the cupolas are occupied, the one by two reverberatory Spiegel furnaces, worked from behind and tapped in front, and the other by a large reverberatory melting furnace similarly worked (with room left for another), capable of melting five-ton charges of iron for conversion. Wide gangways are left between all the furnaces.

The blowing engine room is sixty-six by fifty feet; the engine occupies a space of sixty by twenty-two feet, and consists of a pair of fifty-four-inch air cylinders, water jacketed, a pair of forty-inch steam cylinders, five feet stroke, directly connected and horizontal, and a pair of eighteen by twenty-four-inch vertical air-pumps, worked by bell cranks. The valve motion is the long slide with adjustable slide cut-off valve. The foundations are of heavy dressed stone, leaving a counterarched water-tight pit under and between the engines. The air receiver is eighteen feet high by eight feet diameter. These engines were built by Merrick & Sons, in Philadelphia, and are a strong and excellent job.

The water supply for the whole works is from an unfailing well, twelve feet in diameter, at one corner of the engine-room. A Worthington duplex pump, capable of throwing twelve hundred gallons per minute, and arranged to connect with a ten-inch suction pipe from the river, when required, delivers the water through a ten-inch main into an iron tank twenty feet in diameter and ten feet high, standing on an octagonal brick building twenty-one feet by eighteen and a half feet high, near the rail mill. The tank is covered, and is surrounded by a circular brick wall, with an air space between. From the main, water is carried by underground pipes to the pressure pump and to the feed pumps for the converting and rail mill boilers, to the machine and smith shops, and to the office and hotel. The overflow from the air-pumps runs to a shallow pond five hundred by two hundred feet, behind the rail mill, and when it is cooled runs back into the well. The rail train pit and boshes are drained to the pond. The pressure pump for driving the cranes is of the same size and make as that at Troy, and discharges into an accumulator which also acts as a regulator upon the steam valve. The feed-pump for the converting boilers is of the Henderson pattern. These pumps are in the blowing engine-room. The rail mill feed-pump is a Worthington duplex. By means of an underground connection, the fire hose (always connected) either in the Bessemer works or rail mill, and the cranes, and the boilers in either building, can be supplied from either one of the three last-named steam pumps.

The converting boilers, seven in number, are fifty-four inches by thirty feet, with two seventeen-inch return flues, and form a battery forty-eight by sixty feet in plan, with an ample space all around it. They are enclosed in brickwork, supported by iron staves. The blow-off pipes in the rear lead to the main sewer. The water supply arrangement, safety apparatus, etc., are very complete. The flues from the boilers lead to a brick stack one hundred and ten feet high by five and a half feet square within. A nine-inch wrought-iron steam pipe runs underground, in an enclosed air space, from these boilers to the main steam pipe of the rail mill.

RAIL MILL.—The striking feature of this mill is its ample floor-space, and height. It is the only mill in this country built especially for steel, and the arrangement and strength of machinery are designed accordingly. The furnaces, eight in number (with room for more), are arranged in pairs, at one end and in one wing, with boilers over them, and sheet-iron chimneys outside the building. The furnaces do not front each other, and the smallest space in front of a furnace is twenty-one feet; the mill is consequently cool. In the centre of the space between the furnaces and the rolls, there is ample room for piling ingots, and a hydraulic crane for unloading them from the converting-room cars, and loading them on the furnace buggies. The rail train is near the centre of the building, with the engine at one end, directly connected; the saw carriage in the rear of it is arranged to receive rails from either of two sets of finishing rolls. The hot bed, laid on posts and rollers, is forty-eight feet long, with a twenty-four feet table at one end and a straightening plate at the other. Beyond it is a ten-feet gangway, with a railway running from a turntable in the main siding to the other wing of the mill, in which there are two steam hammers. Beyond this gangway there is a cold bed seventy-two feet long, with a straightening press at one end and punching and drilling machines at the other. Outside of this end of the mill are tables for finished rails, ample yard room, and a siding with a twenty-five ton track scale, leading to the main siding.

The furnaces and boiler setting are of the Fritz pattern, built by Matthews & Moore, in Philadelphia. The furnace-plates are corrugated, to prevent cracking by expansion. The boilers are thirty feet long by four and a half feet diameter, with two seventeen-inch flues, twenty-one by twenty-four inch domes, and eighteen by twenty-one inch feed-chambers below. The flame passes through the flues and under the boiler, in the same direction. The boiler-setting is similar to that in the Troy mill. The feed-pipes are wrought-iron, the main being five inches in diameter. The main steam-pipe is fourteen inches diameter, of wrought-iron, and the branches are five inches diameter, with S expansion-joints. A seven-inch wrought-iron feed-pipe connects the hammer boilers in the wing, with the others. All the steam-pipes are thoroughly lagged with paper, hay-rope, and plaster—a thorough non-conductor, and very inexpensive.

The rail-train engine is of the Fritz pattern, vertical and non-condensing, and was built by Pusey, Jones & Co., at Wilmington, Del. The cylinder stands on four piers, bolted to a solid heavy bed-plate, twenty-four inches high. It is forty inches diameter by sixty inches stroke, and develops three hundred to five hundred horse power at the different passes. The cross-head is above the cylinder, and a forked connecting-rod (thus very long) passes down both sides of it to the crank underneath. The valve-motion is the Fritz revolving cam, with two double steam and two double exhaust puppet valves. The cut-off is performed by the regulator in the steam-pipe. The shaft journals are seventeen inches in diameter and thirty-six inches long. The fly-wheel is thirty feet in diameter and weighs fifty-three tons.

The rail-train is the heaviest in this country, and consists of four sets of three high twenty-three-inch rolls—one set for blooming ten-inch ingots, one for roughing, one for finishing, and one for either finishing rails of another pattern or for rolling beams or blooms. All parts of the train are stronger by some fifty per cent. than similar trains for iron. Each shoe stands on a foundation of heavy dressed stone, fourteen feet deep and four and a half feet thick at the bottom. This train has already run some three months on steel rails, with remarkable smoothness. It was built by Matthews & Moore, in Philadelphia.

The fan engine (fourteen by fifteen inches), fan and feed pump, stand near the main engine at one side of the main building. The fan was built by Morris, Tasker & Co., and is eight feet in diameter, by three feet nine inches face, and delivers to an underground brick air-duct six feet deep by four feet wide, with sixteen inch branches to each pair of furnaces. The saw apparatus, and the straightening and punching machines, are driven by separate engines, and were built by Matthews & Moore. There is no line-shafting in the mill.

In the hammer-wing, before referred to, there is a five-ton Thwaites & Carbutt vertical steam hammer with a forty-ton block, a fifteen-ton crane, and a heating furnace and boiler similar to the others described, and adapted to cogging ingots and to miscellaneous forging. There is also a one-and-a-half ton Morrison hammer by Sellers, with a two-ton crane and a similar heating furnace and boiler. This makes a very complete forge, capable of working up all ingots of unsuitable size for rails, and of producing every class of forging, up to say ten inches.

The present products of these works are steel rails, hammered and rolled blooms, and forgings.

THE FREEDOM IRON AND STEEL WORKS,

at Lewistown, Pa., were the fourth Bessemer works started in this country, and are now producing steel forgings and ingots for rails. The Bessemer plant consists of a pair of five-ton converters and apparatus, on the English plan, and mostly built in England. The blowing engine is vertical, and was built by Messrs. I. P. Morris & Towne, in Philadelphia. The iron is melted in cupolas. The works are equal in quality to the best in England. A very heavy plate mill, driven by a Ramsbottom reversing engine, is completed, and a rail mill and a crucible steel works are in progress. A tyre mill and eight hammers of different sizes are in operation. The iron tyres and other products of the Freedom Iron Works are well known. The Company also runs four charcoal blast furnaces, and owns some forty-five thousand acres of woodland, and extensive mines of ore, much of which is suitable for Bessemer pig.

THE CLEVELAND ROLLING MILL COMPANY'S

Bessemer Works, at Newburgh, six miles from Cleveland, Ohio, are nearly completed, and will be running within a month. They are connected with the company's present furnaces and rolling mills, and are situated between the lines of the Atlantic and Great Western and the Cleveland and Pittsburg Railways. On both these lines, within sixty miles, are large deposits of bituminous coal, of various qualities. Cleveland is the principal outlet of the iron and ores of the Lake Superior region, most of which are well adapted to Bessemerizing. The best raw coal and coke irons in this country, are made within a circuit of seventy-five miles from the works. Railway supplies for the West and Northwest, and lake and manufacturing machinery, are already furnished